THE BACTERIOLOGICAL, CHEMICAL and PHYSICAL REQUIREMENTS for COMMERCIAL EGG CLEANING

Marketing Research Report No. 740

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Service
In cooperation with
The University of California Agricultural
Experiment Station

PREFACE

This report covers research conducted under a project dealing with the development of improved methods, techniques, and equipment for cleaning eggs. The basic and developmental work was carried on under the Research and Marketing Act contract No. 12–25–010–1093, "Designing, Constructing, and Testing an Experimental Egg Cleaner," at the University of California, at Davis, under supervision of Dr. A. W. Brant of the Department of Food Science and Technology. The results of a later phase covering testing of the experimental cleaner under actual commercial operating conditions by Department of Agriculture personnel will be covered in a subsequent report. The Department's contracting officer designated as Federal representative W. H. Elliott, Chief, Handling and Facilities Research Branch, Transportation and Facilities Research Division.

Trade names are used in this publication solely to provide specific information. Mention of a trade name does not constitute a guarantee or warranty and does not signify that the product is approved to the exclusion of other comparable products.

CONTENTS

SUMMARY

A thorough laboratory study of typical egg spoilage organisms under a variety of time and temperature conditions established parameters within which shell eggs could be washed commercially with a minimum hazard to quality. The results showed that the wash water temperature needs to be considerably higher (at least 20°) than egg temperature. The concentration of spoilage organisms in the water is critical, indicating that the practice of recirculating wash water rather than expending it continuously is a serious hazard to keeping quality. The length of immersion (in the washing medium), whether 1, 3, or 5 minutes, is not so important as has been generally thought to be the case.

Field tests of a number of commercial egg cleaners now in use in commercial egg grading and packing plants show that all but one did a fair to poor job of cleaning, although the one that cleaned well checked too many eggs. Some of the tested equipment introduced spoilage organisms into the eggs being cleaned because of the operating methods employed.

Based on the findings of the laboratory studies and the field tests of existing cleaners, an experimental cleaner was designed, constructed, and laboratory tested. Findings show the experimental equipment cleaned effectively with minimum breakage and spoilage hazard.

THE BACTERIOLOGICAL, CHEMICAL, AND PHYSICAL REQUIREMENTS FOR COMMERCIAL EGG CLEANING

By A. W. Brant, food technologist, Phoebe Betty Starr, bacteriologist, and John A. Hamann, investigations leader [1]

INTRODUCTION

The widespread increase in cleaning of eggs during the marketing process, the ineffectiveness of most commercial cleaning equipment, the cost of cleaning with equipment that generally has to be used out of line in the highly mechanized operations in grading and packing plants, and concern over spoilage hazards involved in cleaning prompted this study. The basic microbiological problems involved have been reviewed in a prior publication.[2]

This report is divided into three main sections: Laboratory studies of egg spoilage organisms, field tests of different types of commercial cleaners, and laboratory tests of an experimental cleaner.[3]

The first part of the report concerns the interrelationships of time, temperature, concentration of bacteria, and chemical content of wash water as they bear upon the susceptibility of eggs to bacterial invasion.

The second part reports field tests of commercial egg cleaners, employing different cleaning techniques, to determine their effectiveness and influence on egg breakage and spoilage.

The third part deals with the development of an optimum cleaning technique based on the findings in parts one and two, and with the laboratory tests of an experimental cleaner designed to clean eggs effectively at commercial handling rates with minimum hazard to keeping quality.

The laboratory studies were carried out in the Department of Food Science and Technology, University of California at Davis. The field tests of commercial equipment were conducted in egg grading and packing plants in California and Washington, and on large commercial California farms engaged in their own egg-washing operation. Laboratory-scale tests of the experimental cleaner were conducted in the University's pilot plant facilities in Cruess Hall.

LABORATORY STUDIES OF SPOILAGE AS RELATED TO CLEANING OF EGGS

SELECTION OF TEST ORGANISMS

The first step in selecting test organisms was to choose at random 15 cultures of typical egg-spoilage organisms (*Pseudomonas* spp.). These cultures, isolated from fluorescent eggs in 1948 and 1949 and lyophilized at that time, were opened into a 1-percent yeast-extract broth. After 24 hours, the cultures were streaked onto 1.5-percent yeast-extract agar. Isolated colonies were fished and restreaked as many times as necessary to obtain a pure culture. When the cultures were 24 hours old, the cells were examined microscopically and their size, shape, motility, and Gram reaction noted. Also noted was type of growth on 1-percent yeast-extract agar.

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[1] A. W. Brant and Phoebe Betty Starr, Department of Food Science and Technology, University of California, Davis; John A. Hamann, Transportation and Facilities Research Division, Agricultural Research Service, United States Department of Agriculture, Washington, D.C.

[2] Brant, A. W., and Starr, Phoebe Betty. some physical factors related to egg spoilage. Poultry Sci. 41: 1468–1473. Sept. 1962.

[3] The design features, construction and operating requirements, and field tests of the experimental cleaner by Department personnel will be reported later.

Three of these cultures [4] and one of *Pseudomonas polycolor* (PP2) [5] were tested for infectivity by the following method.

Eggs, which had been prewarmed to 95° F. for 24 hours, were dipped for 5 minutes in a 59° suspension adjusted to 10^6 cells per milliliter and a pH of 6.8. The dipping medium for PP2 was a diluent of 0.25 percent peptone-distilled water; for cultures VI, VIII, and XII, a diluent of 0.125 percent buffered distilled water (BDW) [6] was employed. Five liters of suspension were necessary for complete submersion of the eggs. At the end of the immersion time, the eggs were removed and allowed to air-dry at room temperature (85° daily maximum). The holding temperatures were 59°, 79°, and 90° (table 1). Infection (presence of fluorescence) was determined by examining with an ultraviolet candling lamp and confirmed by breakout of egg contents under ultraviolet light. Figure 1 shows the results for each of the organisms producing significant levels of infection at the various storage temperatures.

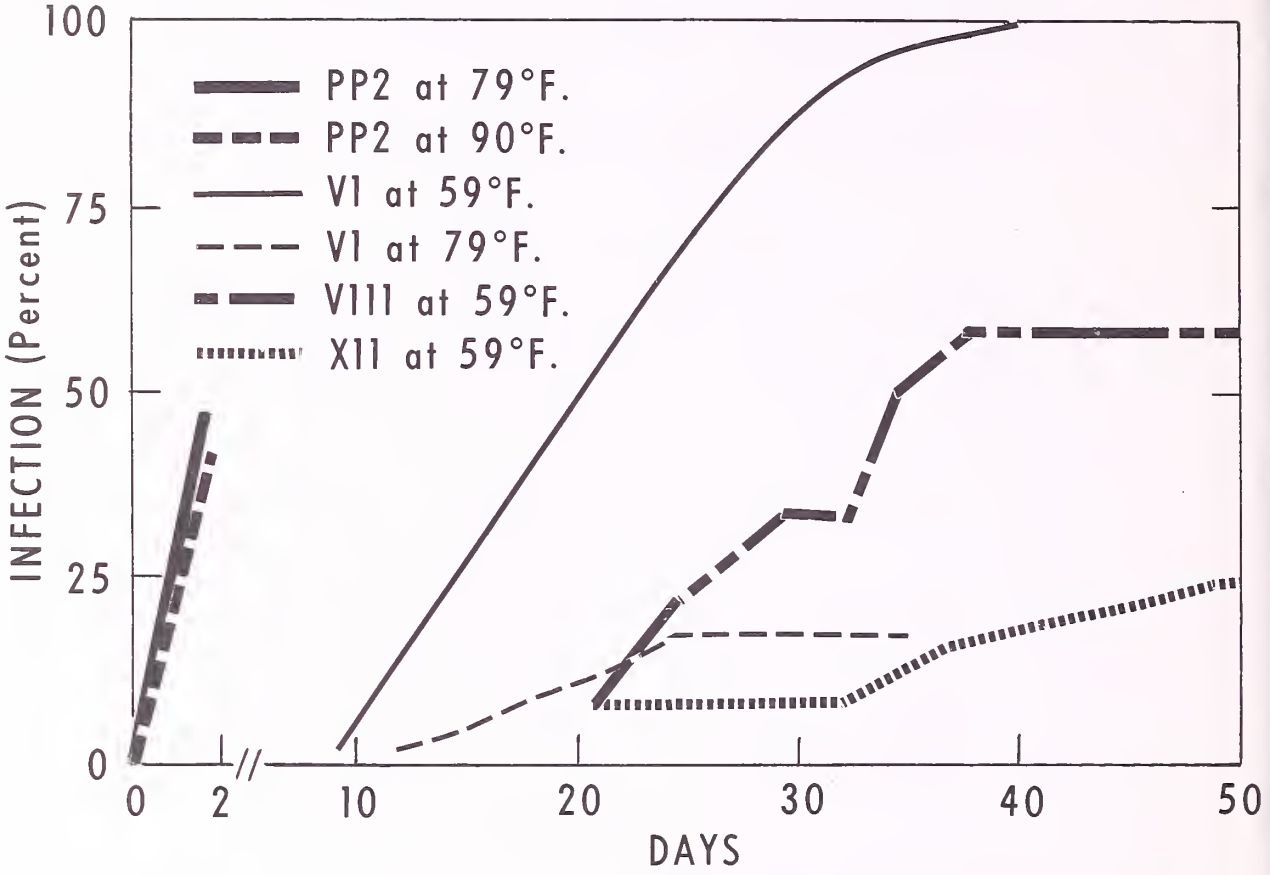


FIGURE 1.—Infection rate of four strains of *Pseudomonas* spp. inoculated into shell eggs subsequently held at different temperatures (59°, 79°, or 90° F.).

TABLE 1.—*Inoculation schedules and holding temperatures*

Organism	Eggs dipped	Eggs stored at—		
		59° F.	79° F.	90° F.
	Number	*Number*	*Number*	*Number*
PP2	36	12	12	12
VI	300	180	60	60
VIII	36	12	12	12
XII	36	12	12	12

The eggs dipped in a suspension of PP2 and incubated at 79° and 90° F. fluoresced, within 2 days, at levels of 49 and 42 percent, respectively. Since PP2 did not grow readily at 59°, results at this incubation temperature are not shown in the figure. With organism VI, fluorescence occurred slowly; after 20 days at 59°, fluorescence was detected in 50 percent of the eggs and after 43 days in 100 percent. Organism VI at 79° showed only 18 percent infection after 30 days. Organism

[4] *Original label* — *New designation*
314 egg Ps — VI
T2–8 — VIII
SF Sour 1 XXV — XII

[5] Selection of *Pseudomonas polycolor* is described in the reference cited in footnote 2.

[6] 3.4 g. KH_2PO_4, 17.5 ml. 1*N* NaOH in 100 ml. distilled water.

VIII at 59° was quiescent for 20 days and gradually displayed 57 percent fluorescence after 41 days. Organism XII at 59° grew very slowly with no infection detectable until 34 days, and the maximum was reached at 24 percent after 50 days. Fluorescence did not develop with organism VI at 90°, nor with organisms VIII and XII at 79° and 90°.

Because of rapid development of fluorescence by PP2, the organism was used as the test bacterium for most of the inoculation experiments; culture VI was used in some of the experiments. These organisms were studied extensively with regard to their sensitivity to various diluents to determine which diluent would best maintain the desired concentration of bacteria during the time required for inoculation experiments.

Many different diluents were used, including peptone, tapwater, distilled water, buffered distilled water, and salt solutions ranging in concentration from 0.85 percent to 12 percent. Plate counts were taken and pH determinations were made, hourly up to 6 hours, and after 24 and 48 hours. The diluents in which the organisms were suspended were held at room temperature (75° ±5° F.) during the entire sampling period; the plates were incubated at 79° F. for 48 hours before counting.

Figures 2 and 3 show the effects of the various diluents on survival of the test cultures. A 0.5-percent solution of buffer concentrate in distilled water (0.5-percent BDW) resulted in the least amount of killing of either organisms on initial contact with the diluent, the least fluctuation of numbers while in contact with the solution during the testing period, and the least change of pH during the period.

Several other diluents retained satisfactory numbers of organisms during the test period—peptone even produced an increase—but they were discarded for various reasons. Some failed to maintain a relatively constant pH (e.g., the lower levels of NaCl), and others were of unknown or variable composition (e.g., sea salt in tapwater). Others, notably the higher concentrations of salt, resulted in rapid decreases in numbers. Thus 0.5-percent BDW seemed the diluent of choice and was used throughout subsequent experiments.

TEMPERATURE DIFFERENCES BETWEEN EGGS AND IMMERSION MEDIUM

It has long been known that when shell eggs are immersed in a liquid medium colder than themselves, the liquid medium will be drawn through the shell pores. If the medium happens to be a water suspension of spoilage bacteria, as would be the case in some washing methods or when eggs sweat, spoilage usually results. However, not known was the exact temperature difference ($\triangle T$) required between eggs and the immersion medium to prevent spoilage in the presence of other variables, such as the concentration of bacterial cells in the medium or the exposure time to the medium. These variables were studied in a series of tests in which eggs were dipped in media that ranged from as much as 100° warmer to 40° colder. Also studied were the effects of rinsing and drying eggs after immersion in the medium. The plotted data from each series of dipped eggs shows a so-called infection curve.

These curves are presented in figures 4 to 9. The standard inoculation technique used in the tests is described below.

Standard Inoculation Technique

1. Fresh nest-clean eggs not older than 72 hours were obtained from the Poultry Farm of the University of California, Davis.
2. The eggs were candled with ordinary light to remove those with cracks, blood, and other defects.
3. The required number of eggs for the day's operation was adjusted for 18 to 24 hours to their required temperature (generally 75° F.).
4. The test organism was grown on a 1-percent yeast-extract agar slant for 24 hours at 79° F. The culture was harvested by washing off the slant with 0.5-percent BDW. The turbidity of the concentrate was measured with a Klett-Summerson Colorimeter, with a No. 54 filter used. Calibration curves showing cell concentration versus turbidity had previously been established.
5. Approximately 8 liters of 0.5-percent BDW was placed in a glass container (10-liter capacity) and adjusted to the particular immersion temperature involved. An appropriate amount of stock culture was added to give the desired population density.
6. Two samples of the medium were then removed aseptically. On one, a pH reading was obtained; on the other, a plate count was made.
7. Two baskets (neoprene-covered or stainless steel), each filled with 24 eggs, were immersed simultaneously. The top basket was removed after 1 minute of immersion time, the second, after 3 minutes of immersion time. The temperature was readjusted and a third basket of 24 eggs was immersed for a period of 5 minutes.
8. After each three baskets of eggs, samples were again taken for pH reading and for plating. The temperature of the bath was recorded. The inoculum was then discarded and steps 4, 5, 6, and 7 were repeated.
9. The eggs were drained in the basket, then placed on sterile filler flats and allowed to air-dry at room temperature.
10. The eggs were placed in clean cases and stored at 79° F.
11. Periodically, the eggs were candled with an ultraviolet lamp for fluorescence. Positives were confirmed by breakout.

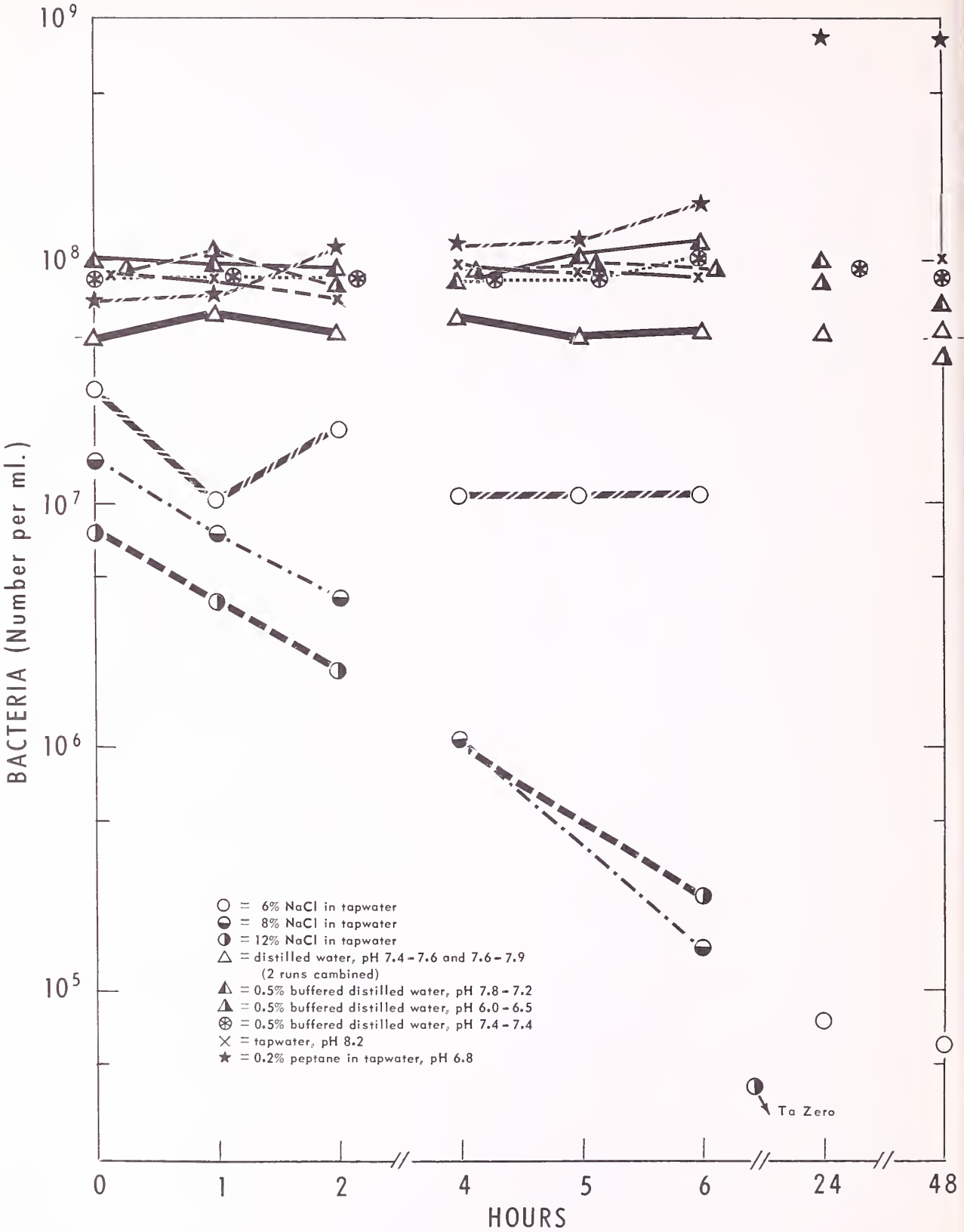


FIGURE 2.—Survival of *Pseudomonas polycolor* (PP2) in different diluents.

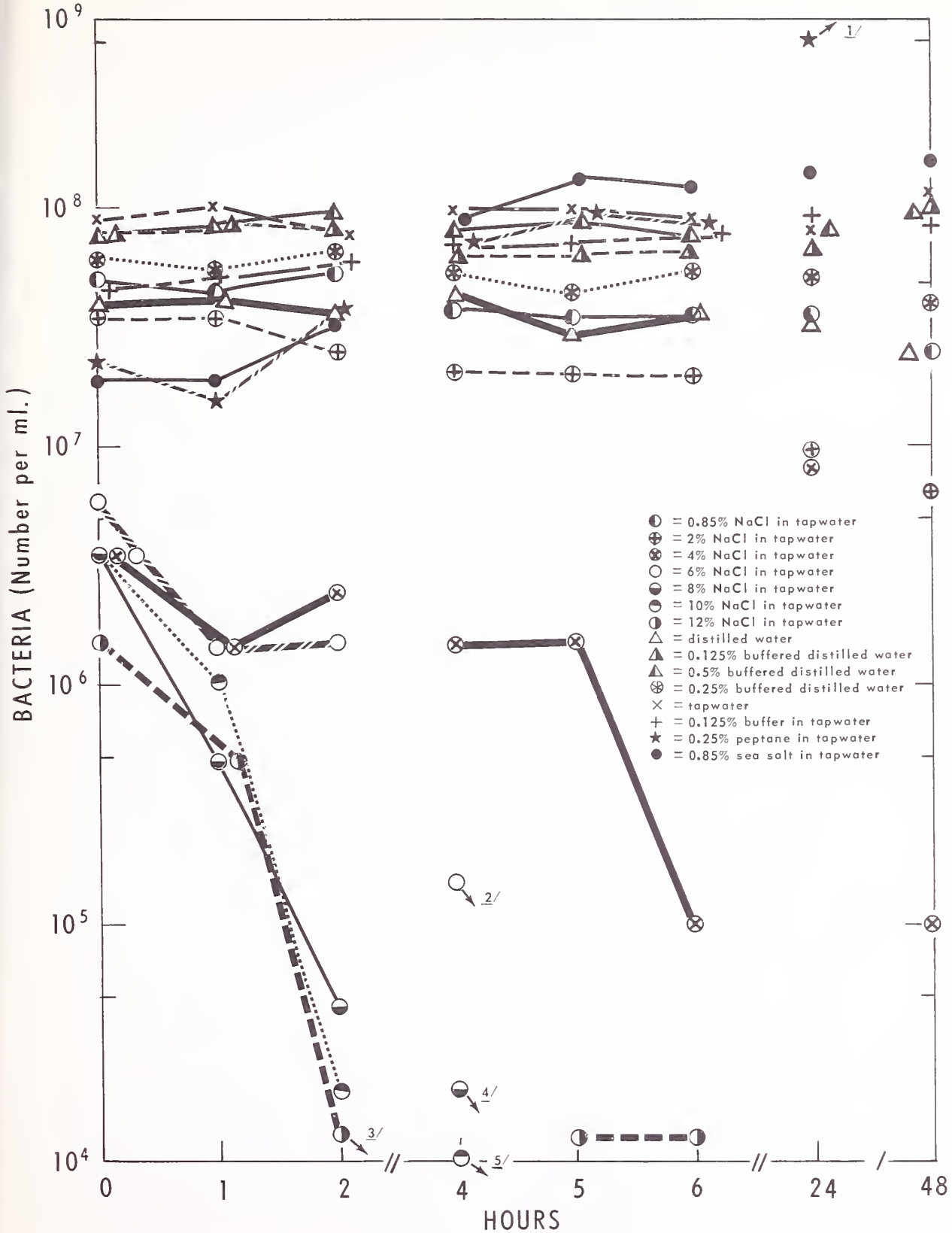


FIGURE 3.—Survival of *Pseudomonas* spp. (strain VI) in different diluents. The reference numbers have the following meanings: [1] To 10^9 at 48 hours; [2] to 10^3 at 5 hours; [3] to 10^2 at 4 hours and back up to 10^4 at 5 and 6 hours; [4] to 10^3 at 5 and 6 hours; and [5] to 10^3 at 5 and 6 hours.

12. At the end of 7 or 8 weeks, the remaining eggs were candled as in procedure 11, washed by hand in a detergent-sanitizer containing a quaternary ammonium compound [7] (400 p.p.m.) to remove surface bacteria, rinsed under running tapwater, placed on sterilized filler flats, and allowed to air-dry.[8]

13. After drying, the eggs were opened under a desk ultraviolet light to check for fluorescence, and the contents and shells were placed in separate sterile mason jars.

14. The contents were thoroughly mixed in a laboratory blender [9] with no additions. The shells were mixed with 99 ml. of sterile 0.5 percent BDW before blending.

15. Each jar was then sampled for bacterial plate counts by means of a medium designed to favor the development of fluorescent colonies (Flo Agar).[10]

Factors Involved in Washing: Cell Concentration, Immersion Time, and Initial Egg Temperature

Results of tests of three variables on infection of eggs, as related to the temperature differential between the eggs and immersion medium, were plotted as infection curves. Figures 4, 5, and 6 show curves for cell concentration, immersion time, and initial egg temperature, respectively, averaged across all the other conditions imposed. These curves show that water temperature (the immersion medium) needs to be considerably higher than egg temperature—at least 20° F.—to keep egg spoilage to a minimum.

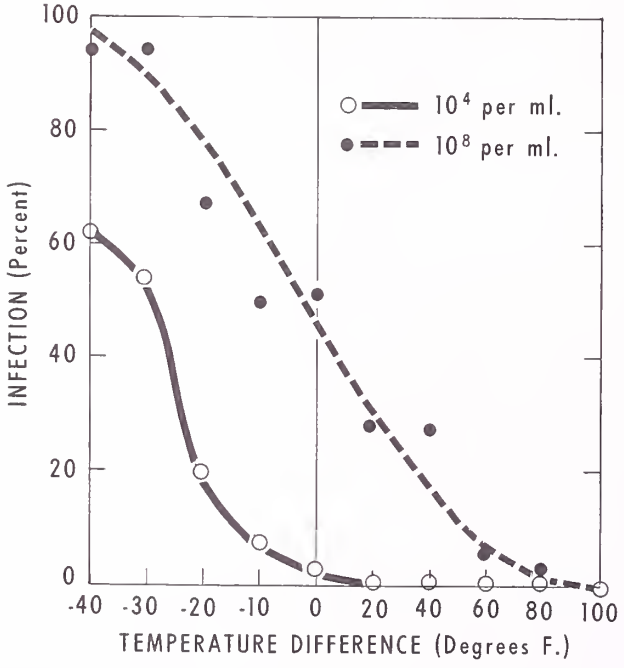


FIGURE 4.—Effect of cell concentration on incidence of fluorescence in eggs dipped in a medium containing *Pseudomonas polycolor*. Temperature difference=temperature of the immersion medium minus egg temperature.

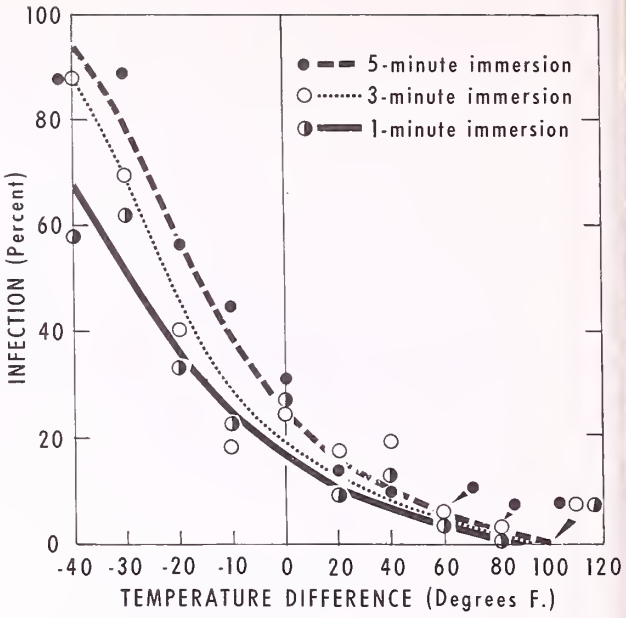


FIGURE 5.—Effect of immersion time of eggs in a medium containing *Pseudomonas polycolor* on incidence of fluorescence. Temperature difference=temperature of the immersion medium minus egg temperature.

The effects of cell concentration on infection are clearly shown in figure 4. At the higher bacterial count, infection occurred despite temperature differences that should not have allowed entry of the bacteria into the eggs, indicating that low bacterial counts as well as a proper temperature differential must be maintained. This would mean that the wash water in a commercial machine should not go above 1,000 to 5,000 bacteria per milliliter.

Figure 5 indicates that an immersion time of 1 minute is sufficient for infection if other conditions are right and that longer exposure does not appreciably affect the problem. It appears that immersion time is not critical for infection and therefore can be altered to contribute to best cleaning.

Initial egg temperature (fig. 6) appears to have an effect in favor of cooler eggs. One possible

[7] Active ingredients: A quaternary ammonium chloride, 3 percent; trisodium phosphate dodecahydrate, 15 percent; sodium carbonate anhydrous, 17 percent; inactive ingredients, 65 percent.

[8] Sterilized (autoclaved) rubber gloves were worn. Detergent-sanitizer solutions and rinse water temperatures were higher than egg temperatures at all times.

[9] The blades and rubber gaskets, after being used, were sterilized by immersion in 70 percent alcohol for 15 minutes and allowed to air-dry.

[10] KING, E. O., WARD, M. K., and RANEY, D. E. TWO SIMPLE MEDIA FOR THE DEMONSTRATION OF PYOCYANIN AND FLUORESCIN. Jour. Lab. and Clin. Med. 44 (2) : 301–307. 1954.

Proteose Peptone #3, 2 percent; Bacto Agar, 2 percent; Glycerol, 1 percent; K_2HPO_4 (Anhydrous), 0.15 percent; $MgSO_4 \cdot 7H_2O$, 0.15 percent; pH adjusted to 7.2.

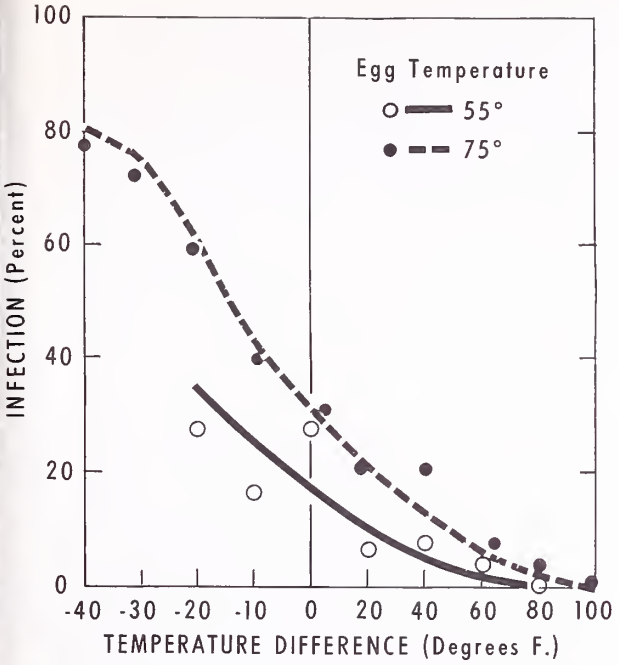


FIGURE 6.—Effect of initial egg temperature on incidence of fluorescence in eggs dipped in a medium containing *Pseudomonas polycolor*. Temperature difference=temperature of the immersion medium minus egg temperature.

explanation is that the drying and subsequent holding of the warmer eggs resulted in their cooling a little, whereas the cooler eggs were mostly in a warming-up situation. This would suggest that the drying and subsequent cooling following washing requires additional study.

From data obtained in other experiments, it was decided that studying the influence of dirty eggs on temperature differential and egg infection would contribute no useful information. Dirty eggs were found to be highly contaminated on the exterior and to vary internally from no infection to a high number of organisms. This degree of variability would have made it impossible to interpret data from tests of temperature differential and egg infection similar to those just discussed. Moreover, naturally occurring organisms would not have shown any effect in as short a time as the rapidly developing test organism *Pseudomonas polycolor*.

Tests that involved rubbing the eggs were also ruled out because the standard technique developed included rubbing the eggs in a detergent-sanitizer solution containing a quaternary ammonium compound. In preliminary testing of the standard procedure, rubbing was found to affect only surface organisms. The purpose of the infection curves was to measure organisms within the shell pores or the interior of the egg.

Effects of Rinsing

In the rinsing tests, the standard procedure for inoculation was followed, except that iron was added to the immersion medium (20 p.p.m. of Fe^{++} as $FeSO_4 \cdot 7H_2O$).[11] Two series of tests were run. In one series, the PP2 cell concentration of the baths was adjusted to 10^8 organisms per milliliter; in the other, no bacterial concentrate was added.

For each immersion temperature, 3 baskets, each containing 24 eggs at 75° F., were immersed for 5 minutes. At the end of the immersion time, 1 basket of eggs was set aside; 1 was rinsed under running sterile distilled water; and 1 was rinsed by dipping 20 times in a detergent-sanitizer solution containing a quaternary ammonium compound at 400 p.p.m.,[12] followed by a rinse with sterile distilled water. The temperature of the various postimmersion rinses was 10° higher than that of the bath in each case.

All the eggs were air dried on autoclaved molded pulp filler flats and incubated at 80° F.

Results in the rinsing tests were determined in two categories: Organisms on shell surfaces and organisms in shells and contents.

ORGANISMS ON SHELL SURFACES.—Five prelabeled eggs, taken from each of the three baskets for each immersion temperature, were pressed at four points (small and large ends, once each; middle, two spots) onto a 2-percent flo agar plate. The touch plates were made before immersion, between immersion and rinsing, and before and after drying. The touch plates were incubated at room temperature, and 48 hours later the results were recorded. Determination of quantitative data was not feasible for this test. Subjective scoring showed that the number of organisms on the eggshell surface after rinsing, compared with preimmersion number of organisms, was (1) moderately reduced by the sterile water rinse, (2) greatly reduced by the quaternary rinse, and (3) unchanged or higher for the control group (not rinsed).

ORGANISMS IN SHELLS AND IN CONTENTS.—Eggs immersed in the medium containing PP2 were opened at the end of 3 days. Eggs immersed in the medium with no bacterial concentrate were opened at the end of 14 days. All the contents and shells were inspected with an ultraviolet lamp for fluorescence, and all contents and shells from the eggs immersed in the medium with no bacterial concentrate were cultured.

For the eggs immersed in PP2, there were substantially no differences among the postimmersion treatments in the numbers of spoiled eggs developing with any of the immersion temperatures (fig. 7). For all three postimmersion treatments, there was an increase in the number of fluorescent albumens as the eggs were subjected to colder and colder inocula. At a +20° F. differential, spoilage was very low or nonexistent. However, some infection did occur when the temperature of the bath was only slightly above the egg temperature.

[11] GARIBALDI, J. R. FACTORS IN EGG WHITE WHICH CONTROL GROWTH OF BACTERIA. Food Res. 25: 337. 1960.

[12] See footnote 7, p. 6.

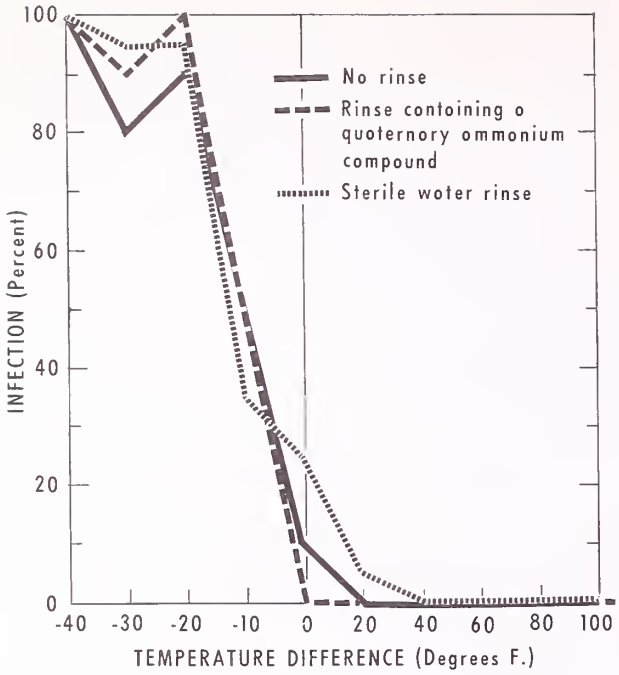


FIGURE 7.—Effect of postdipping rinses on infection of eggs dipped in a medium containing 20 p.p.m. of Fe^{++} and PP2.

For temperature differentials between 0° and 20°, eggs rinsed in water alone had a higher level of infection than eggs receiving no rinse or subjected to a rinse containing a quaternary ammonium compound. In the studies in which eggs were not subjected to rinsing treatments (see figs. 4, 5, and 6), infection was observed at higher differentials (+60° F. or more).

Of the eggs immersed in the bacteria-free baths, none had fluorescent albumens. A few fluorescent shell spots were observed from all treatments in which the temperature of the dipping medium was lower than the egg temperature. However, with all postimmersion treatments, the eggs receiving no artificial contamination had numerous organisms present in the contents and shell when there was a large negative temperature differential between the egg and diluent (figs. 8 and 9). As $\triangle T$ was reduced from −40° to 0° F., this "normal" flora generally decreased. When $\triangle T$ was positive, bacterial counts fluctuated considerably. Increasing the contact of the shells with liquid in the rinse treatments seemed to increase the numbers of bacteria.

In other studies [13] the number of bacteria in shells rinsed in sterile water was compared with the number in those washed in germicide (chlorine and quaternary types) prior to pulverizing. Higher counts were obtained from the shells that had been washed with germicides. It was speculated that these substances helped free organisms from the shell particles. In the present study there appeared to be little difference between the two rinse treatments.

Influence of Drying and Other Conditions

A segment of an infection curve (−20° to +40° F.) was studied to observe the influence of drying by various means on spoilage development. After each immersion of 6 dozen eggs at the selected temperature, one-third of the eggs were placed immediately in a forced-air drying oven at 149° F. for 4½ minutes, cased, and stored at 55°; one-third were air dried at room temperature for 2 to 4 hours and stored uncased at 55°; the remaining third were placed on clean plastic filler flats, cased, and held for 24 hours at 79° before storage at 55°.

The majority of the eggs of each group were opened after 3 days. None had fluorescent albumens or shell spots regardless of the postimmersion drying treatment. After 14 days, two fluorescent eggs were found in the group that had been dipped at $\triangle T = -14°$ F., air dried, and stored uncased at 55°. The lack of development of spoilage at 55° in 3 days was expected since the optimum temperature of growth for PP2 is 79°.

In another series, one of the points of the infection curve was selected, $\triangle T = -14°$ F., and two organisms, PP2 and VI, were used. Half of the eggs dipped in PP2 were air dried and the other

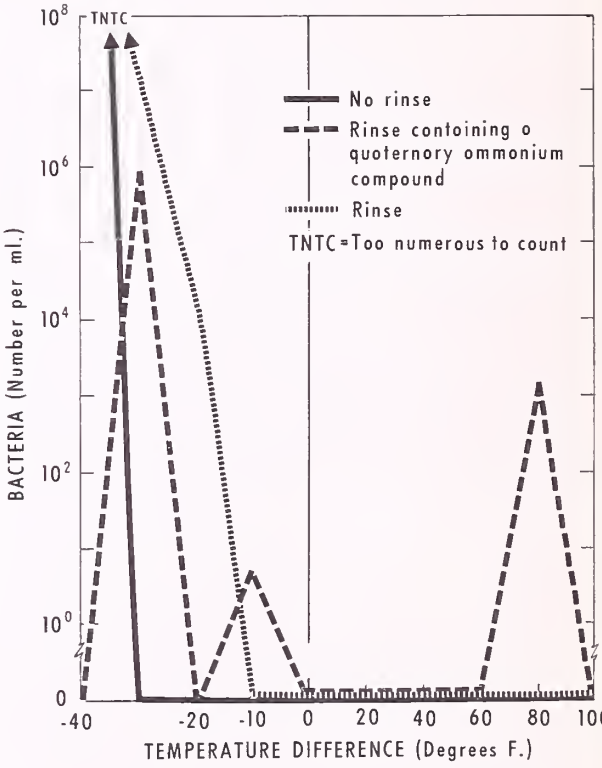


FIGURE 8.—Incidence of bacteria in egg contents after dipping eggs in a bacteria-free iron solution (20 p.p.m.), rinsing, and holding for 14 days at 80° F.

[13] PENNISTON, VIRGINIA, and HEDRICH, L. R. THE REDUCTION OF BACTERIAL COUNT IN EGG PULP BY USE OF GERMICIDES IN WASHING DIRTY EGGS. Food Technol. 1: 240–244. 1947.

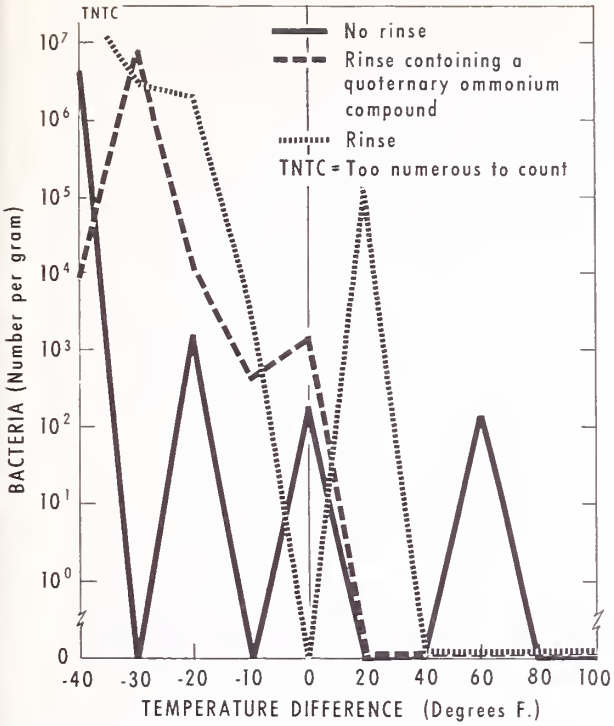


FIGURE 9.—Incidence of bacteria in eggshells after dipping eggs in a bacteria-free iron solution (20 p.p.m.), rinsing, and holding for 14 days at 80° F.

half were oven dried. The eggs dipped in organism VI were air dried only. Half of all the air-dried eggs were stored at 55°, and the rest were incubated at 79° (with the oven-dried eggs).

Spoilage developed in the PP2-inoculated eggs within 3 to 4 days at 79° F. regardless of the type of drying (table 2). There was a slightly smaller percentage spoiled in the oven-dried group. At the end of 23 days at 55° F., there was no spoilage in either group, but 42 percent of the air-dried group had fluorescent shell spots.

The eggs inoculated with organism VI (air-dried eggs only) had 29 percent spoilage after 4 days at 79° and 63 percent after 13 days at 55°.

In all these tests, the spoilage rates paralleled the respective temperature requirements of each of the organisms.

TABLE 2.—*Influence of drying on spoilage of eggs*

Organism	Incubation		Spoilage	
	Time	Temperature	Oven-dried eggs	Air-dried eggs
	Days	*° F.*	*Percent*	*Percent*
PP2	3–4	79	41	50
	8	79	71	89
	23	55	0	[1] 0
VI	4	79	--------	29
	13	55	--------	63

[1] Fluorescent shell spots were found on 42 percent.

To measure the spoilage potential of organisms on the shell surface, a series of tests was devised involving the addition of iron and lowered pH. The tests were suggested by the work of Garibaldi [14] in which it was shown that high pH inhibits Gram-negative spoilage organisms by reducing the availability of iron. Nest-clean eggs under 48 hours of age either were dipped for 3 minutes in isothermic BDW containing 10^4 PP2 or 10^8 organism VI per milliliter, at a $\triangle T$ of at least $-15°$ F., or were left untreated. After the dipped eggs had been allowed to dry, 48 egg samples from each group were subjected to the following prestorage treatments:

(1) Three-minute dipping in BDW containing 20 p.p.m. of Fe^{++} as $FeSO_4 \cdot 7H_2O$, at a $\triangle T$ of $-15°$ F.
(2) Placing in a desiccator, evacuating, and then releasing the vacuum with CO_2. In 2 hours the pH of the egg white was reduced to 7.3.
(3) Dipping in a colorless, tasteless mineral oil.
(4) Combinations of 1, 2, and 3.

All the eggs were held at 70° F. Half were examined after storage for 14 days and the remainder after 28 days.

The bacterial population of eggs that received neither immersion nor prestorage treatments ranged from 10^1 to 2×10^4/ml. and was the same after 28 days. The bacterial population on the shell increased in the eggs that received prestorage treatments but no immersion. It became 2×10^7/ml. by the end of 28 days. Similar bacterial counts were found in the 28-day-old eggs coated with PP2 and those inoculated with VI. Since the numbers of bacteria in the shells after 28 days were essentially the same in all three experimental groups, two of which included known spoilers, it seems that the initial number and types of bacteria on the shell were not as important as some of the experimental conditions.

The spoilage data are shown in table 3.

Neither nest-clean nor PP2-coated eggs showed any great tendency to spoil at 70° F. with any of the prestorage treatments. The 70° temperature, although known not to be optimal for PP2, was expected to induce more spoilage, under the length of storage and the various treatments, than did occur. The nest-clean eggs used in this series of tests apparently carried no natural flora whose growth was accelerated by the treatments imposed. Organism VI, however, responded as expected to all treatments. The addition of iron or the lowering of pH, or both, greatly increased its spoilage capacity at 14 days, but at 28 days no additive effects were noted. Apparently, the addition of oil alone gave some boost to organism VI since at 14 days there was a difference between the oil-treated group and the group with no treatment, the percentage of spoilage being 75 and 33 percent, respectively.

[14] See footnote 11, p. 7.

TABLE 3.—*Spoilage of nest-clean eggs dipped in contaminating solutions and stored at 70° F., as affected by various treatments before storage*

Treatment just before storage	Spoilage of nest-clean eggs that were—					
	Dipped in solution containing organism PP2 and stored—		Dipped in solution containing organism VI and stored—		Undipped and stored—	
	14 days	28 days	14 days	28 days	14 days	28 days
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
None	0	0	33	91.6	0	0
Fe	----------	----------	[1] 96	96.0	0	[2] 4.2
Oil	8.4	4.2	75	91.6	0	0
Fe and oil	0	0	[1] 95	100.0	0	0
CO_2 and oil	4.2	8.4	100	100.0	0	0
Fe, CO_2, and oil	4.2	[3] 4.2	[1] 100	[4] 83.0	0	0

[1] In 7 days. [2] Black rot. [3] Sour—nonfluorescent. [4] In 14 days.

FIELD TESTS OF COMMERCIAL EGG CLEANERS

The second phase of the study involved observation, testing, and evaluation of performance of the principal types of commercial cleaners in operation at the time of the study. The tests were conducted in commercial egg grading and packing plants or on large commercial farms on the west coast, and in the laboratory at Davis, Calif.

TEST AND SCORING PROCEDURES

In selected plants, one case of dirty eggs and one case of clean eggs were drawn from the stock of eggs on hand for each washer. All eggs were examined for cracks and the cracked eggs were discarded. The dirty eggs were scored for degree of dirtiness according to the following classification system:[15]

Score 1—¼ or less of shell surface covered.
Score 2—¼ to ½ of shell surface covered.
Score 3—½ to ¾ of shell surface covered.
Score 4—¾ to all of shell surface covered.

The types of soiling identified were fecal material, blood, wiremark, yolk, litter stain, and mud or soil. A half case of unwashed eggs was gathered at random to be used as a control.

Several cases of nest-run eggs were washed in each machine studied before the test eggs were run through. The two preselected cases of cleans and dirties were then run through the washer, placed on flats, cased, and returned to the laboratory for examination. The dirties were scored a second time to determine the extent of dirt removal; both cleans and dirties were candled for cracks and placed in storage at 50° F.

At intervals of 1 day, and 1, 2, 4, and 8 weeks, at least 20 eggs of each category (washed dirties, washed cleans, and unwashed controls) were selected at random for albumen quality and bacteriological evaluation. The procedures for bacteriological examination were steps 12 through 15, of the standard inoculation technique (pp. 3, 6). Periodically, touch plates were run before and after shell surface sterilization. When the eggs were opened into sterile petri dishes under a desk ultraviolet lamp to check for fluorescence, albumen height was measured for Haugh unit calculations. All the remaining eggs were broken out and checked for fluorescence and rots after 16 to 24 weeks' storage.

For the purpose of accelerated-spoilage studies, 24 eggs of each treatment were selected at random at intervals of 1 day and 2 weeks postwashing, prewarmed overnight to 75° F., and immersed 5 minutes at 55° in a solution containing 20 p.p.m. of Fe^{++} but no organisms. The eggs were then stored at 80° for 14 days, after which they were examined as in steps 12 through 15 of the standard inoculation technique.

At the end of each of the field tests, samples of wash water were obtained from each machine for the following determinations:

(1) Available chlorine or quaternary ammonium compounds: Commercial test kits were used.

[15] Concerning U.S. Standards for quality of individual shell eggs, see REGULATIONS GOVERNING THE GRADING OF SHELL EGGS AND UNITED STATES STANDARDS, GRADES, AND WEIGHT CLASSES FOR SHELL EGGS. EFFECTIVE JULY 1, 1964. U.S. Dept. Agr. January 1965.

(2) Bacteriological counts: As aseptically as possible, the various water samples were collected in sterilized bottles while the test eggs were being washed. Immediately, three drops of a sterile 10-percent solution of sodium thiosulfate was added per 100 cc. to neutralize any residual chlorine present. The sample bottles were then wrapped in plastic bags, packed in ice, and taken to the laboratory: the contents were plated the next morning.

(3) Iron content of the water: A full bottle of the water feeding into the machine was collected and analyzed for iron content in the laboratory.[16]

All the glassware used had been washed in 20 percent aqua regia. Sometimes, in addition to the water sample collected specifically for iron assay, the samples collected for bacteriological counts were also assayed for iron. Whenever a sample contained organic material, 5 ml. of the water being tested was mixed with an equal quantity of 5 percent trichloracetic acid, then centrifuged for 10 minutes. The supernatant was decanted and used for the determination.

EVALUATION OF FIELD TESTS

Table 4 shows a disappointing level of dirt removal for all but machine G. The increase in cracks due to machine handling ran rather high. Much of the increase in the number of cracked eggs in the machines was probably due to the loading operation rather than the machines.

Cleaning effectiveness was reduced as the age of the eggs increased prior to washing. In the data shown for machine A, the low reduction in dirty eggs (3.4 percent) occurred with eggs that were washed several days after laying; the 32.8 percent reduction was in eggs washed within a short period after laying. Similarly, machine C cleaned all but 3.7 percent of the dirties when the eggs were washed shortly after laying, but when washing was delayed several days, 27.8 percent of the dirties remained. Machine G cleaned eggs well even when the washing occurred several days after the eggs were laid.

Cleaning effectiveness of the machines was greatest when the degree of dirtiness before washing was low.

Attempts to clean eggs in the various egg washers had no important effect on albumen quality (table 5). A few of the differences in Haugh units were statistically significant, but the order of magnitude was small. Furthermore, the frequency of statistical significance did not exceed that expected for the number of comparisons. Available commercial machines and washing methods, it is concluded, do not present any nonmicrobiological hazard to interior egg quality.

The bacteriological results after eggs were stored 4 weeks indicate that in general the washers increased bacterial populations in the shells of the eggs washed (table 5). To a much less extent, this was also true of the egg contents. Four-week data were chosen for the table as being typical of the length of time present-day fresh eggs usually remain in market channels. As expected, dirty eggs had highly contaminated shells with few exceptions; occasionally this was reflected in contents also.

[16] SMITH, G. F. THE COLORIMETRIC DETERMINATION OF IRON IN RAW AND TREATED MUNICIPAL WATER SUPPLIES BY USE OF 4, 7 DIPHENYL-1, 10 PHENANTHROLINE. Analyst 77 (917) : 418–422. 1952.

TABLE 4.—*Cleaning effectiveness and shell damage of commercial egg cleaners and cleanliness scores of eggs, field tests*

Machine [1]	Soiled eggs			Average cleanliness score [3]		Total increase in cracked and lost eggs by washing [4]
	Before wash [2]	After wash [2]	Reduction	Before wash	After wash	
	Percent	*Percent*	*Percent*			*Percent*
A	44. 3	40. 9	3. 4	2. 0	1. 6	5. 3
A	34. 5	1. 7	32. 8	1. 4	. 5	7. 8
B	42. 1	9. 8	32. 3	1. 7	. 6	2. 1
C	34. 3	3. 7	30. 6	1. 5	. 5	2. 8
C	54. 2	27. 8	26. 4	1. 8	1. 4	4. 3
D	33. 1	6. 4	26. 7	1. 5	. 3	1. 7
D	25. 7	5. 3	20. 4	1. 6	1. 1	3. 3
D	28. 7	15. 1	13. 6	1. 4	1. 0	1. 9
E	15. 9	9. 5	6. 4	1. 2	. 9	3. 1
F	26. 4	11. 4	15. 0	1. 3	. 9	1. 3
G	35. 3	4. 2	31. 1	1. 7	. 2	3. 9
H	53. 9	23. 9	30. 0	1. 8	1. 3	5. 0
I	31. 1	16. 7	14. 4	1. 5	1. 1	2. 0

[1] Machines are not identified as to type to avoid manufacturer identification. 13 machines were studied in 10 plants. Machines of the same type are designated by the same letter.
[2] Eggs ¼ to completely soiled (combined 2, 3, and 4 scoring, p. 10).
[3] Eggs less than ¼ to completely soiled (combined full scoring, p. 10).
[4] Percent of all eggs (cleans and dirties) cracked and lost after washing minus percent cracked prior to washing.

TABLE 5.—*Haugh unit values and bacterial counts of washed clean and dirty eggs from field-test commercial cleaners, determined after 4 weeks' storage at 50° F.*[1]

Machine[2]	Haugh units (average)			Bacteria per gram of shells and per ml. of contents					
				Control[3]		Cleans		Dirties	
	Control[3]	Cleans	Dirties	Shells	Contents	Shells	Contents	Shells	Contents
A		65	63			467	0	935, 000, 000	65, 000, 000
A	75	75	75	193	0	5, 120	8, 130	13, 600, 000	41, 000
B		58	60			0	0	0	0
C		76	67			153, 500, 000	65, 000	166, 500, 000	11, 000
C	72	77	75	132	575	5, 970, 000	2, 160	20, 800, 000	1, 202, 000
D	65	67	57	0	0	28, 600	5, 900	6, 450, 000	420
D	71	76	76	1, 220	0	0	0	9, 050	0
D	71	70	73	[4] 17, 000	0	[4] 34, 027, 000	76, 500	[4] 12, 666, 000	3, 575, 000
E	68	68	72	1, 340	1, 740	30, 200	0	78, 500, 000	19, 000, 000
F	72	76	75	0	0	0	0	1, 230	0
G	75	70	76	25, 000	0	0	0	2, 083, 000	300
H	70	64	71	0	0	0	0	[4] 549, 000	0
I	73	74	72	0	0	0	0	15, 300	0

[1] 20 eggs minimum examined from each machine for each treatment.
[2] See footnote 1, table 4.
[3] Mixed clean and dirty in nest-run proportions.
[4] Fluorescent colonies on plate.

TABLE 6.—*Spoilage (fluorescent and total rots) of washed clean and dirty eggs from field-test commercial cleaners, determined after 16 to 24 weeks' storage at 50° F.*[1]

Machine[2]	Control, not washed		Clean, washed		Dirty, washed	
	Fluorescent rots	Total rots	Fluorescent rots	Total rots	Fluorescent rots	Total rots
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
A	2. 2	5. 4	0	3. 6	0	18. 4
A	4. 0	14. 1	2. 0	38. 0	9. 6	35. 5
B			1. 0	2. 5	0	15. 2
C	2. 5	10. 0	17. 5	70. 7	18. 8	72. 3
C	. 5	7. 3	5. 0	55. 3	8. 0	43. 3
D	2. 1	4. 3	19. 5	28. 9	8. 7	38. 9
D	0	1. 9	0	3. 4	0	10. 9
D	4. 5	11. 9	8. 0	46. 6	16. 3	55. 0
E	0	3. 3	12. 3	30. 3	21. 0	92. 1
F	0	0	0	1. 4	. 9	7. 6
H	2. 9	3. 4	3. 9	8. 3	7. 9	13. 0
I	0	0	0	2. 4	4. 2	11. 4

[1] 20 eggs minimum examined from each machine for each treatment.
[2] Machines are not identified as to type to avoid manufacturer identification. Machines of the same type are designated by the same letters.

TABLE 7.—*Spoilage of field-test eggs stored 16 to 24 weeks at 50° F. and field-test eggs dipped in iron solution [1] 1 day and 14 days after washing and held 14 days at 80° F.*

Machine [2]	Iron-dipped at 1 day, held 14 days			Iron-dipped at 14 days, held 14 days			Controls (not dipped in iron, held 16 to 24 weeks)		
	Control, not washed	Clean, washed	Dirty, washed	Control, not washed	Clean, washed	Dirty, washed	Nest-run, not washed	Clean, washed	Dirty, washed
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
A	4. 2	33. 3	58. 3	4. 2	0	16. 6	14. 1	38. 0	35. 5
C	0	25. 0	20. 8	4. 2	20, 8	16. 6	7. 3	55. 3	43. 3
D	0	4. 2	8. 3	0	8. 3	25. 0	4. 3	28. 9	38. 9
D	0	0	0	0	4. 2	0	1. 9	3. 4	10. 9
D	12. 5	20. 8	50. 0	12. 5	50. 0	54. 3	11. 9	46. 6	55. 0
E	0	25. 0	16. 6	0	25. 0	8. 3	3. 3	30. 3	92. 1
F	4. 2	16. 6	8. 3	0	0	8. 3	0	1. 4	7. 6
H	8. 3	25. 0	12. 5	0	8. 3	12. 5	3. 4	8. 3	13. 0
I	4. 2	12. 5	16. 6	0	4. 2	8. 3	0	2. 4	11. 4
Weighted average	3. 7	18. 1	21. 3	2. 3	13. 4	16. 7	5. 1	21. 5	30. 0

[1] 20 p.p.m. of Fe^{++} and no organisms.
[2] Machines are not identified as to type to avoid manufacturer identification. Machines of the same type are designated by the same letter.

Hazards to keeping quality encountered with the field-test washing equipment and methods employed are shown in table 6. Nearly all samples showed a decided increase in spoilage due to washing. The relatively high levels of spoilage in the controls are probably caused by the high storage temperature (50° F.) for the length of time involved (16 to 24 weeks).

The accelerated spoilage studies showed that the percentage of spoilage was remarkably close to the final spoilage (the amount found in undipped eggs after 16 to 24 weeks' storage) (table 7). It was also found that accelerated spoilage could be induced as long as 14 days postwashing. The presence of significant correlations was revealed (table 8).

TABLE 8.—*Correlation coefficients between spoilage of field-test eggs stored 16 to 24 weeks at 50° F. and field-test eggs dipped in iron solution 1 day and 14 days after washing and held 14 days at 80°*

Eggs and washing treatment	Iron dipped at—		Degrees of freedom
	1 day	14 days	
Nest-run unwashed control	0. 37	[1] 0. 77	7
Clean, washed	. 49	. 63	7
Dirty, washed	. 44	. 35	7
All combined	[2] . 54	[2] . 59	25
All washed combined	[2] . 60	[2] . 47	16

[1] Probability less than 5 percent that this result was due to chance.
[2] Probability less than 1 percent that this result was due to chance.

Table 9 shows that the most reliable way of avoiding high bacterial counts in the wash water is not to recirculate the water. Bacteriological contamination of the water in all the washers of the recirculating type was high as soon as the first few eggs were washed. Very low levels of iron were encountered, except for one well sample not being used for washing. None of the water samples contained quaternaries. Only chlorine-type sanitizers were encountered. Cost was assumed to be the influencing factor. The highest level of chlorine during machine operation was 48 p.p.m.; most had 24 p.p.m. or less. In all cases, the owner had added the compounds according to the manufacturer's directions.

TABLE 9.—*Bacterial count, iron content, and sanitizer found in water of commercial egg washing machines used in field tests*

Machine [1]	Water-sample source	Run No.	Iron content of water	Bacterial count per milliliter	Chlorine found in wash water
			p.p.m.	*Number*	
A	Water pipeline	1	----------	310	Yes
		2	----------	1, 960	
	Tank water	1	----------	0	
		2	<0. 10	7, 000	
	Rinse water	1	----------	0	
		2	----------	0	
A	Tank water	----------	1. 20	524, 000	Yes
	Rinse water	----------	0	27, 000	
	Drain water	----------	1. 20	314, 000	
B	----------	----------	----------	----------	Yes
C	----------	----------	----------	----------	Yes
C	Tank water	1	<. 01	8, 125	Yes
		2	<. 01	4, 755	
		3	<. 01	39, 500	
D	Tank water (after 9 cases)	----------	----------	24, 000	Yes
	Tank water (after 12 cases)	----------	----------	60, 000	
	Rinse water	----------	. 01	0	
D	Water pipeline	----------	. 06	0	Yes
	Tank water	----------	3. 80	4, 550	
	Well water (not used in washer)	----------	9. 80	----------	-----
D	Water pipeline	----------	. 03	----------	Yes
	Tank water	----------	. 17	----------	
	Rinse water	----------	. 17	----------	
E [2]	Wash water	1	----------	0	Yes
		2	<. 10	0	
	Rinse water	----------	----------	0	
F	Wash water [3]	----------	----------	3, 300	Yes
	Tank water	----------	<. 10	70	
G	No. 1 tank water	----------	----------	64, 600	No
	Overflow water	----------	. 45	1, 340	
	No. 2 tank water	----------	1. 20	14, 000	
	Overflow water	----------	----------	11, 000	
H [2]	Wash water	----------	. 13	76	No
	Rinse water	----------	. 20	134	
	Drain water	----------	. 15	106, 000	
I [2]	Wash water	1	----------	0	Yes
		2	<. 10	0	
	Drain water	----------	----------	42, 000	

[1] See footnote 1, table 4.
[2] Nonrecirculating water.
[3] After passing over eggs but prior to return to tank.

THE EXPERIMENTAL CLEANER

A major purpose of the laboratory and field studies was to arrive at a cleaning technique that would then be incorporated into the design of an experimental washer. Several features of the technique were based on observations of existing machines and were not the subject of experimental testing. Other features came directly from test and research findings.

1. A satisfactory egg-cleaning machine should incorporate—
   a. A dirt-softening area with provision for the incorporation of wetting devices to the extent required by the severity of the dirt removal problem.

      Great variation in degree and type of egg soiling is encountered in the field.

This varies primarily with type of flock management (e.g., cage versus floor) and season of the year. Soiling increases with wet weather; therefore, heavy soiling periods will vary from one part of the country to another.

b. A dirt-removal area involving the use of water, detergents, and the optional use of abrasives. Water and detergents are essential components of an egg-cleaning solution.

c. A finishing area including, but not limited to, a sanitizing rinse and optional supplemental cleaning.

d. A drying area so arranged that completely dried eggs will be delivered to the egg-grading operation.

Rapid drying of eggs has long been known to reduce spoilage hazards. In the field studies poor drying was encountered in nearly all operations.

2. The water supply system should permit the expending of the wash and rinse water continuously while providing an economical level of water consumption.

3. At all times, a positive temperature gradient of at least 20° F. should be maintained between cleaning medium and internal egg temperature.

The infection curves developed in the laboratory studies showed that less than a 20° F. differential between the eggs and the cleaning medium would not prevent infection.

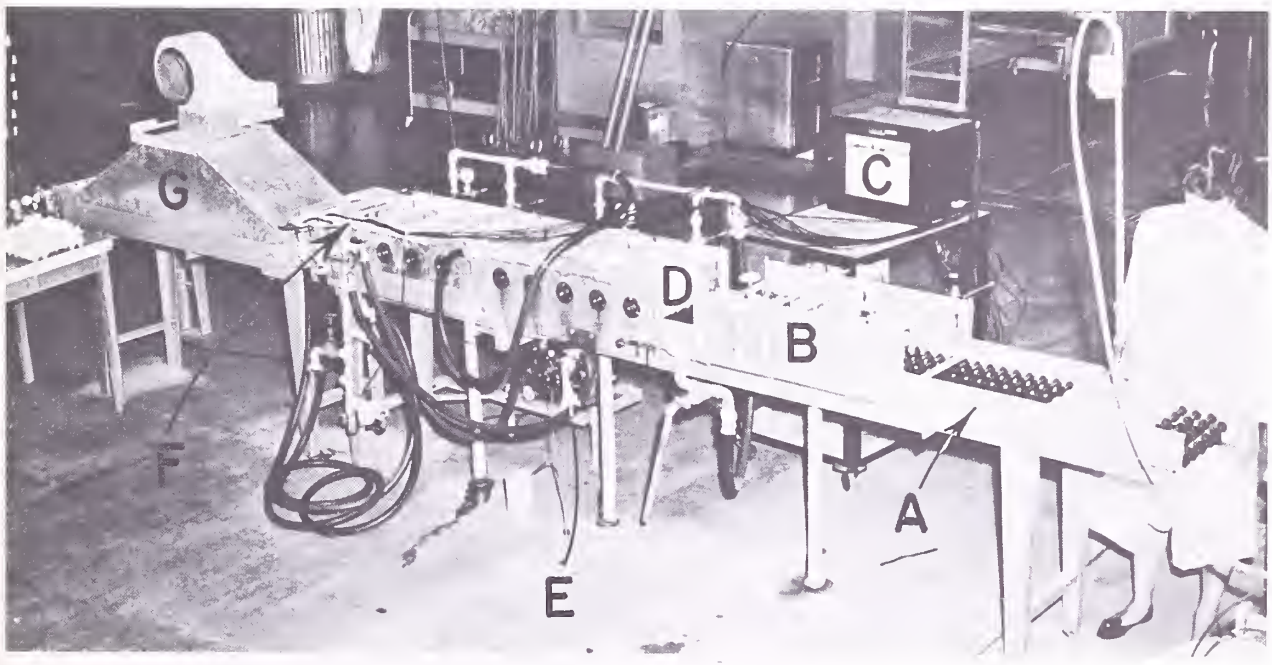
DESCRIPTION

Based on the time and temperature parameters determined in the laboratory studies of egg spoilage organisms and the findings disclosed in the field tests of commercial egg cleaners, an experimental cleaner was designed and constructed.[17] As results in the various tests became available, structural features and operating requirements were developed.

The experimental cleaner (fig. 10) equipped for laboratory testing provided sufficient unobstructed roller conveyor space for the line loading operation, a shell-wetting area suggested by observations during the field tests, a temperature recording device that maintained a printed record of water temperatures at a number of critical points to verify the proper temperature gradient (determined in the laboratory studies), a scrubbing area, a device for rotating the eggs in the scrubbing area (not visible in illustration), a device (proportioner) for metering a detergent sanitizer into the wash water, a rinsing area, a device for transferring rinsed eggs to a dry roller (not visible in illustration), thermocouples at all water outlets within the unit (wetting, washing, and rinsing), a drying area with hood and blower, and a device for transferring cleaned eggs to packing operation (partly visible in illustration).

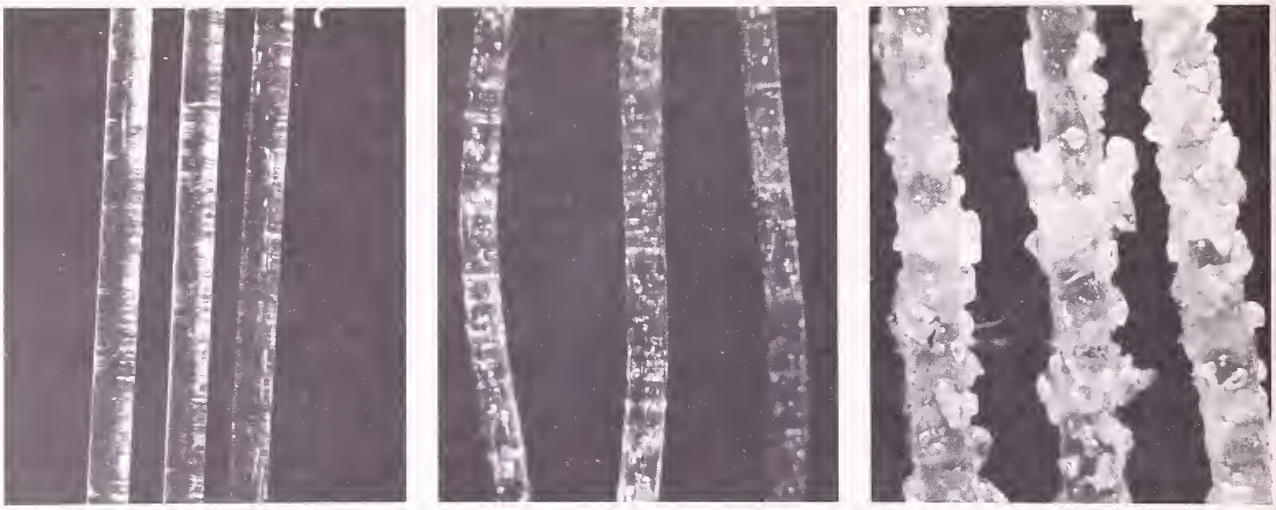
To avoid the spoilage hazard involved in reuse of wash water and still keep the costs of water and

[17] See footnote 3, p. 1.



BN–22452

FIGURE 10.—Experimental cleaner employed for laboratory tests: (A) Loading area, (B) wetting area, (C) temperature recording device, (D) scrubbing area, (E) metering device for detergent sanitizer, (F) thermocouples at water outlets in rinsing area, and (G) blower in drying area.



(A) BN–22314 (B) BN–22316 (C) BN–22317

FIGURE 11.—Magnified views of nylon bristles: (A) Plain nylon; (B) abrasive-impregnated nylon; and (C) plain nylon treated with an epoxy adhesive and abrasive.

heating to an economical level, high-velocity, low-volume spray nozzles were used. Sets of six nozzles each were spaced so that a jet of water would be in direct line with an egg several times throughout the wetting and rinsing areas as the egg alternated between short forward motion while rotating, and a brief hesitation. The water jets were cone shaped in the wetting area and fan shaped in the rinsing area. Rotating brushes, plain and contoured to the shape of the eggs, were used at a wide range of r.p.m. until optimum speeds were achieved.[18]

Optimum cleaning of heavily soiled eggs required addition of abrasive to the bristle surface of several ranks of brushes. Plain bristles, contour-cut bristles with an abrasive impregnated in the bristle filament, and plain bristles with abrasive attached by epoxy adhesive were used (fig. 11).

The problem of moist eggs at the time of packing was overcome by transferring them to a drying conveyor at the end of the rinsing area and blowing warm air over them. Transferring the eggs to a separate conveyor avoided the problem of having also to dry roller-conveyor surfaces that were being moistened continuously. At the end of the dryer, the direction of product flow is changed so that the cleaner can be installed at right angles to most grading and packing lines, thereby reducing the overall length of line in a cleaning, grading, and packaging situation. After the experimental cleaner was adjusted for continuous, smooth performance, laboratory tests were undertaken.

TEST PROCEDURES AND RESULTS

Twenty-four-hour-old clean eggs and nest-run [19] eggs with natural shells (not oiled) were obtained from three egg producers in the Sacramento area. On 3 consecutive days, the needed quantity of each type was collected. A total of 33¾ cases (12,150 eggs) was used.

In the laboratory, the large ends of the eggs were marked with indelible ink, making it possible to select random samples from each of the sources for examination during the entire experiment.

Before treatments, all eggs were candled and all those with cracks and unsound contents were discarded. The remaining eggs were scored for adhering dirt by means of the scoring system previously described (p. 10). Half of the nest-run eggs were dipped in mineral oil that had been heated to 120° F. Thus, three major groups were established:

Group A—nest-clean eggs, unoiled.
Group B—nest-run eggs, unoiled.
Group C—nest-run eggs, oiled.

Each group contained an equal number of eggs from each ranch. All the eggs were stored overnight at approximately 50° F. The morning following each of the 3 collection days, half the eggs in the above groups were washed.

Preliminary to sending the test eggs through the washing machine each day, a case of nonexperimental eggs was washed. The order of the test lots was randomized so as to avoid a situation wherein eggs with similar shell condition followed each other.

During the washing operation, all of the water temperatures were automatically recorded on a multipoint thermocouple recorder (fig. 10). The average water temperature at the nozzles in the shell-wetting area was approximately 95° F. The nonrecirculated water entering the brush cabinet

[18] High speeds lifted eggs out of their position on the rollers, causing much breakage.

[19] Mixed clean and dirty in proportions as they occur at time of gathering on the farm.

(scrubbing area) averaged approximately 102°; the rinse-water temperature averaged approximately 101°. There was a 3° to 5° temperature drop in the water in the brush cabinet between the nozzles and the eggs. The effective water temperature therefore was 97° to 99°, which maintained the desired temperature gradient. The water pressure was 20 p.s.i.; the conveyor belt moved at a rate of 20 cases per hour; the brushes turned at an average rate of 194 r.p.m.

A liquid nonionic surface active agent with extremely low foaming properties (a benzyl ether of octyl phenol) was used. The detergent concentrate was made up of 30 percent orthophosphoric acid (85 percent), 15 percent nonionic surface active agent, and 55 percent water. The pH was 2.3. The stock solution for the proportioner, 25.6 percent detergent concentrate and 74.4 percent water, was injected into the wash-water line by a metering device at the rate of 0.73 ounce per gallon. The use solution thus contained nearly 220 p.p.m. nonionic s.a. agent, or 0.022 percent, at pH 2.3. Formulation of the use solution is as follows:

150 ml. nonionic surface active agent
300 ml. 85 percent orthophosphoric acid } = concentrate.
550 ml. water

256 ml. concentrate
744 ml. water } = stock solution.

0.73 ounce of stock solution/gallon water = use solution.

Derivation of p.p.m.:

Original solution = 100% benzyl ether of octyl phenol.
Detergent concentrate = 15% of original material.
Stock solution = 25.6% of detergent concentrate.
Use solution = 0.73 ounce of stock solution/gallon.

Therefore, $15\% \times 25.6\% = 0.0384$

0.73 ounce $\times$ 0.0384 = 0.028032 ounce of original material (nonionic surface active agent) in the use solution.

$$\frac{0.028032 \text{ ounce}}{128.0 \text{ ounces}} = \frac{x}{1{,}000{,}000}$$

$$x = \frac{28032}{128}$$

p.p.m. = 219.0

The eggs were dried at the prevailing room temperature. A few eggs retained small amounts of moisture on their shells, showing the need for more heat in the drying air to increase its water-holding capacity.

At the end of the day's run, the machine was thoroughly cleaned. In addition, the washing parts were neutralized by running the machine empty for at least one-half hour with a saturated solution of sodium bicarbonate feeding through the detergent-sanitizer metering device.

All the washed eggs were rescored for adhering dirt and recandled for cracks. The incidence of soiled eggs was reduced to well below 1 percent (table 10), roughly a tenfold reduction. Stated another way, 90 percent or more of all the eggs scoring as dirty before washing were cleaned. Oiling of eggs to be washed appears to enhance the cleaning effectiveness of the machine. The cleanliness scores reflect the great reduction in degree of dirtiness.

TABLE 10.—*Cleanliness scores of eggs and cleaning effectiveness and shell damage of experimental egg cleaner, laboratory tests*

Run No.	Nest-run eggs soiled [1]						Average cleanliness score, nest-run eggs [2]				Soiled eggs cleaned		Cracked eggs and eggs lost by washing [3]		
	Unoiled			Oiled			Unoiled		Oiled		Unoiled nest-run	Oiled nest-run	Unoiled nest-run	Oiled nest-run	Unoiled nest-clean
	Before wash	After wash	Reduction	Before wash	After wash	Reduction	Before wash	After wash	Before wash	After wash					
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*					*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1	8. 4	1. 0	7. 4	9. 2	0. 6	8. 6	0. 7	0. 06	0. 8	0. 04	88	93	4. 7	3. 6	4. 1
2	7. 6	. 7	6. 9	9. 3	. 3	9. 0	. 7	. 05	. 7	. 06	91	97	3. 5	4. 6	2. 3
3	4. 3	. 4	3. 9	5. 4	. 2	5. 2	. 5	. 04	. 6	. 05	91	96	1. 9	4. 0	2. 1
Average	6. 7	. 7	6. 0	8. 0	. 4	7. 6	. 6	. 05	. 7	. 05	90	95	3. 4	4. 1	2. 8

[1] Combined 2, 3, and 4 scoring. (See p. 10.)
[2] Combined full scoring of clean and soiled eggs. (See p. 10.)
[3] Only sound-shelled eggs were washed.

The incidence of cracked eggs was higher than expected. It was noted, however, that the loading operation and the egg-removal operation contributed substantially to total percentage of cracked eggs. The laboratory technicians used for these operations performed satisfactorily, but not with the dexterity of the experienced personnel of the average egg-packing plant. The actual percentage of eggs cracked by the washer will have to be determined after its installation in a commercial egg room. From observations at the time of the test runs, it is thought highly probable that the cracking incidence produced by the washer itself will be well below the incidence experienced in the field tests of commercial washers. (See table 4.)

Washed and unwashed lots were held in three storage rooms, one each for the temperature and relative humidity combinations averaging 36° F. and 77 percent relative humidity, 52° and 70 percent relative humidity, and 80° and 58 percent relative humidity. After 1, 2, 4, and 8 weeks, about 50 washed and 50 unwashed eggs were randomly selected from each of the storage temperatures for each of 3 types of eggs on each of 3 successive days (table 11). All the eggs were candled before an incandescent lamp. Ten percent of each lot was broken out for Haugh unit measurement. The remaining eggs were then broken out, and the shells and contents were examined under incandescent and ultraviolet lights. Any fluorescence, off-odors, rots, mold development, and white coagulation were noted and recorded.

Albumen quality deteriorated as expected under the storage conditions imposed. No effects of washing were noted. Table 11 shows the number of eggs broken out, by storage and shell condition, and the rot incidence in the stored eggs. While the number spoiled in the washed eggs was higher than it was in the unwashed eggs, the incidence was minor for both. The spoilage rate was 0.25 percent in the washed eggs and 0.14 percent in the unwashed.

Two additional procedures, stated below, reinforced the observations on spoilage:

1. Before storage, 24 eggs were selected from each washed and unwashed group for accelerated spoilage tests. These lots were brought to room temperature and were immersed for 5 minutes in separate containers of sterile buffered distilled water containing 20 p.p.m. Fe^{++}. The temperature of the solution was at least 20° F. lower than the egg temperatures. After draining, the eggs were cased and incubated at approximately 78° for 14 days. At the end of this period, the eggs were candled with ultraviolet and incandescent lamps, then opened for bacteriological culturing according to procedures of the standard inoculation technique (pp. 3, 6).
2. From each washed and unwashed group, a total of 20 eggs, representing the 3 holding temperatures, was selected and combined for bacteriological examination.

TABLE 11.—*Washed and unwashed eggs broken out, with numbers and types of rots found* [1] *by shell condition and storage period and temperature* [2]

[Approximately an equal number of eggs from each of the supply farms in each lot]

Treatment, storage period, and lot	Nest-clean eggs (unoiled) stored at—			Nest-run eggs					
				Unoiled, stored at—			Oiled, stored at—		
	80° F.	52° F.	36° F.	80 °F.	52° F.	36° F.	80° F.	52° F.	36° F.
WASHED EGGS	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
1 week:									
1	50	50	50	50	50	50	50	50	50
2	50	50	50	50	50	50	50	50	50
3	50	50	50	50	50	50	50	50	50
2 weeks:									
1	50	50	50	50	50	50	50	50	50
2	50	50	50	50	50	50	50	50	50
3	50	50	50	50	50	50	50	50	50
4 weeks:									
1	44	30	45	37 (1R)	49	50	54 (1R)	43	51
2	43	45	50	60 (1R)	54	49	60	49	54
3	50	54	42	52 (2S)	49	52	47	50	49
8 weeks:									
1	45	29	46	37 (2B, 1S)	59	48	54	38	50
2	32	43	49	49	54	50 (1B)	43	49	51
3	50	51	40	53 (2B)	49	53	47	50	47
UNWASHED EGGS									
1 week:									
1	50	50	50	50	50	50	50	50	50
2	50	50	50	50	50	50	50	50	50
3	50	50	50	50	50	50	50	50	50
2 weeks:									
1	50	50	50	50	50	50	50	50	50
2	50	50	50	50	50	50	50	50	50
3	50	50	50	50	50	50	50	50	50
4 weeks:									
1	51	41	51	46	50	54	60	39	56
2	56	53	57	58	56	55	53	57	58
3	53	50	59	58	56	44	53	53 (1F)	51
8 weeks:									
1	51	52	52	47	65	56	60	45	56
2	44 (1F)	51	56	46 (2R)	55	57	51	55	53
3	55 (1B)	54	54	58 (1F)	55	45	53	54	49

[1] Number and type of spoiled eggs: (B)=black rot, (S)=sour, (F)=fluorescent, (R)=other rots.

[2] Temperatures are averages. The range in temperatures and the average and range of the relative humidities were as follows:
36° F. (29°–48°); 77% (50%–93%).
52° F. (44°–61°); 70% (52%–91%).
80° F. (73°–93°); 58% (40%–77%).

Bacterial counts were typical for the unwashed, undipped eggs (table 12). After 8 weeks, bacterial numbers were beginning to build up. The counts were on the average higher in the washed eggs, but no important increase in contamination was in evidence. Since the samples from the three holding temperatures were combined, it seems likely that the bacteria encountered came from the high holding temperature. For both washed and unwashed eggs, iron dipping provided an excellent prediction at 2 weeks of the later results. The accelerated tests, showing the presence of some bacteria, indicated that a few eggs would spoil. This was later verified. Spoilage in the iron-dipped eggs was low, similar to that found in undipped eggs.

CONCLUSION STATEMENT

In conclusion, it appears that the experimental egg washer cleans soiled eggs satisfactorily without damaging interior quality or increasing microbiological hazards. Shell damage was higher than desirable; but the exact contribution of the washer will be determined in field tests, at which time cleaning effectiveness and breakage will be compared with those of commercial cleaners. A separate report on the performance of the experimental egg washer under commercial operating conditions will be published.

TABLE 12.—*Bacterial counts of washed and unwashed eggs as related to treatment, storage time, and shell condition, laboratory tests of experimental egg cleaner* [1]

Treatment and storage time	Nest-clean eggs		Nest-run eggs			
			Unoiled		Oiled	
	Shells	Contents	Shells	Contents	Shells	Contents
Washed:	*No./gram*	*No./ml*	*No./gram*	*No./ml*	*No./gram*	*No./ml*
1 week	60, 000	0	6, 900	0	3, 500	0
2 weeks	0	0	20, 000	0	16, 200	0
4 weeks	36, 666, 000	3, 053, 000	83, 362, 000	6, 500, 000	26, 200	0
8 weeks	6, 362, 000	14, 300, 000	1, 666, 800	200	11, 100	800
Iron-dipped, 2 weeks	107, 266, 000	[2]	3, 204, 000, 000	30, 251, 000	16, 446, 000	394, 000
Unwashed:						
1 week	0	0	200	0	2, 000	0
2 weeks	136, 000	0	16, 600	0	110, 400	0
4 weeks	9, 000	0	500	0	300	0
8 weeks	16, 000	0	1, 213, 000	33, 000	10, 633, 000	13, 333, 000
Iron dipped, 2 weeks	6, 866, 000	[2]	3, 532, 000	29, 000	[3] 3, 203, 000	134, 000

[1] Storage temperature groups combined.
[2] Too numerous to count.
[3] A few fluorescent colonies on the plates.

Washington, D.C.

Issued April 1966

U.S. GOVERNMENT PRINTING OFFICE: 1966 O—796–207